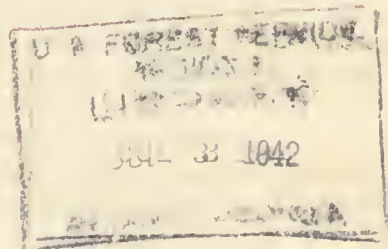
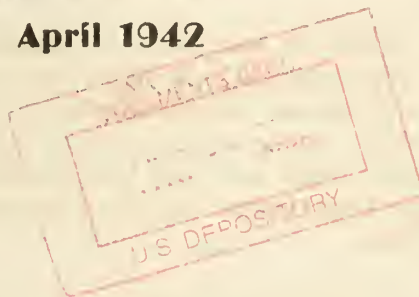


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THE GLUING CHARACTERISTICS OF 15 SPECIES OF WOOD WITH COLD- SETTING, UREA-RESIN GLUES

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THE GLUING CHARACTERISTICS OF 15 SPECIES OF WOOD

WITH COLD-SETTING, UREA-RESIN GLUES¹

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The study here reported was made to compare the gluing characteristics of various species of wood when glued with cold-setting, urea-resin glues, since it is known from previous studies¹ that there are considerable differences in gluing properties among species when gluing with other woodworking glues. The species under test in this preliminary study are those which appear to be of primary importance in war production work. Others may be tested as the need arises.

It was the aim to conduct the tests in such a way that the results could be compared with those obtained previously on the same species when glued with casein glues.²

In addition, tests were made to see if there is any difference in the gluing properties of the heartwood and sapwood of several of the species when glued with urea-resin glues.

Method of Procedure

Species and Method of Selection

In this study, the following species were selected on the basis of their importance at the present time:

ash, white	hickory, pecan	pine, southern yellow
basswood	mahogany	spruce, Sitka
birch, yellow	maple, sugar	sweetgum
Douglas-fir	oak, red	walnut, black
fir, noble	oak, white	yellowpoplar

¹This mimeograph is one of a series of progress reports issued by the Forest Products Laboratory to further the Nation's war effort. Results here reported are preliminary and may be revised as additional data become available.

²U. S. Department of Agriculture Bulletin 1500, entitled "The Gluing of Wood," by T. R. Truax.

Both heartwood and sapwood of the 7 following species were selected and glued separately to determine if there was any difference in their gluing properties:

birch, yellow
hickory, pecan
maple, sugar

oak, red
oak, white

sweetgum
yellowpoplar

Nominal 1-inch lumber was used for all species. The material was so selected that the average specific gravity of each species was approximately equal to the average for the species as listed in U. S. Department of Agriculture Technical Bulletin 479.² The stock was then cut into pieces about 1 by 3 by 14 inches in size. The pieces were placed in a room where the relative humidity was 65 percent and the temperature 80° F., and allowed to remain there until they had reached approximate equilibrium in moisture content. The stock was then between 11 and 12 percent in moisture content.

The blocks of each species were weighed, arranged in order of their weights, and the adjacent blocks were then paired so as to have the blocks of nearly the same specific gravity glued together. As there were 4 glues being used in this study, the pairs of blocks were divided into 4 groups having similar ranges of specific gravity by selecting every fourth set for 1 glue and in like manner for the other glues.

Just prior to gluing, the blocks were cut to a size of 7/8 by 2-1/2 by 12 inches and the faces planed smooth.

Glues and Gluing Conditions

Four commercial cold-setting, urea-resin glues in common use were employed in gluing all the foregoing woods. The 4 glues were made by different manufacturers and were selected as representative of the better brands of the cold-setting, urea-resin glues available. The glues were mixed as directed by the manufacturers and spread with a small mechanical spreader equipped with a rubber roll which was adjusted to deliver a spread of between 20 and 25 grams per square foot.

Assembly periods (interval between spreading and pressing) of 5 and 15 minutes were used to approximate a range commonly used in commercial operations. The gluing pressure was 150 pounds per square inch. This pressure was allowed to remain on the blocks overnight, which gave a pressure period of about 16 hours. The temperature in the gluing room and of the material in the press was maintained between 75° and 80° F.

Four joints (20 test specimens) were glued at each assembly time for each glue, which resulted in 32 joints per species, or 64 joints when the sapwood and heartwood of the species were glued separately.

²"Strength and Related Properties of Woods Grown in the United States," by L. J. Markwardt and T. R. C. Wilson.

After removal from the press, the glued blocks were placed in a 65 percent relative humidity room where they were allowed to condition for 1 week before being cut into test specimens.

Testing

Five shear specimens of conventional design⁴ were cut from each block. These specimens were broken in shear, the load at failure recorded, and the percentage of wood failure estimated.

Results and Discussions

The results of the tests on joints of the various species, averaged for the 4 cold-setting, urea-resin glues, are shown in table 1. For comparison, the results obtained in previous tests with casein glue are also shown.

The species were all well glued and, considering the percentages of wood failure obtained, the joints made with the cold-setting, urea-resin glues appeared generally superior in quality to those glued with casein. The average wood failures of the joints glued with the resin glues ranged from 83 to 100 percent, while those glued with casein ranged from 30 to 99 percent. The better results obtained with the resin glues were most evident on the species of higher specific gravities, such as sugar maple, red and white oaks, white ash, and walnut. From this it appears that there is less difference in the gluing characteristics of the different species when urea-resin glues are used than when the gluing is being done with casein glues.

The average results, based on the 4 glues, for the different species are shown graphically in figure 1. The species are arranged in increasing order of their average specific gravities. Conforming with results of previous experiments with other glues,² the shear strength tends to increase with an increase in specific gravity. From the detailed data also it appears that within a species the denser specimens tend to produce the higher test values.

The joint strength in hickory was abnormally low considering the specific gravity of the wood and the amount of wood failure developed. While hickory showed the lowest wood failure (83 percent) of all the species in this study, it was still sufficiently high to indicate that higher joint strengths might have been expected in view of its high specific gravity (0.71).

The results obtained with each of the 4 resin glues on the 15 different species are shown in table 2. There is very little difference in the results obtained by using the various glues, but Glue B did show somewhat less wood failure and shear strength values, especially in the denser

⁴—Described in U. S. Department of Agriculture Bulletin 1500 and in Army, Navy, and Federal glue specifications.

species. This glue had a tendency to "cake" together upon standing in the container, with the result that it was hard to mix properly. Following the start of the tests, this glue was removed from the market for a short time, but has since been returned.

The data in table 3 indicate that there is no consistent difference in the results obtained with the 5- and 15-minute assembly times on the different species and the averages for all the 15 species are identical. Within these limits good joints can be obtained with urea-resin glues.

Heartwood and Sapwood

In table 4 the results of gluing the heartwood and sapwood are shown for 7 species. Allowing for the differences in specific gravity between the specimens of heartwood and sapwood used, only hickory showed a consistent difference in strength and wood failure between heartwood and sapwood. In the case of sweetgum, the lower percentage of wood failure obtained with the heartwood, as compared with the sapwood, is consistent with the higher shear strength and specific gravity of the heartwood. Normally, of course, there is no consistent difference in specific gravity between sapwood and heartwood.

Summary

The results of tests on the gluing of 15 species of wood with 4 cold-setting, urea-resin glues indicate:

In general, all the species tested can be glued with urea-resin glues to produce joints as strong in shear as the wood itself. Hickory appears to be somewhat more difficult to glue than the other species. In general, the shear strength of the joints increased as the specific gravity of the woods used in making the joint increased.

The average wood failures were generally higher on joints glued with the urea-resin glues than were obtained previously on the same species glued with casein glues. The wood failures of the resin-glued joints were fairly uniform for all the species tested. This is in contrast with a general decline in wood failures with an increase in specific gravity of the wood of casein glued joints.

There was very little difference in the results obtained among the 4 urea-resin glues used in this study, although one of the glues showed slightly lower strengths and wood failures on the denser species.

Joints of essentially equal quality were obtained for assembly periods of 5 and 15 minutes.

No significant difference in gluing properties was found between heartwood and sapwood in the 7 species compared with the possible exception of hickory for which the heartwood appeared to be somewhat more difficult to glue than the sapwood.

Table 1.--Comparison of the results of gluing 15 species with cold-setting, urea-resin and casein glues

Species	Urea-resin glues ¹				Casein glues ²			
	Speci-	Average ³	Average	Specific ⁴	Average ³	Average	Specific ⁴	
	mens	shear	wood	gravity	shear	wood	gravity	
	aver-	strength	failure	of	strength	failure	of	
	aged	:	:	wood	:	:	wood	
	Number	Lb. per	Percent		Lb. per	Percent		
	:	sq. in.	:		sq. in.	:		
Ash, white.....	160	2,265	96	0.59	2,810	42	0.64	
Basswood.....	160	1,441	97	.40	1,700	42	.45	
Birch, yellow ⁵ ..	320	2,840	96	.61	2,680	40	.71	
Douglas-fir.....	160	1,636	97	.49	1,800	77	.51	
Fir, noble.....	160	1,632	98	.42	1,452	99	.40	
Hickory, pecan ⁵ ..	320	2,016	83	.71	2,800	63	.66	
Mahogany.....	160	1,924	99	.47	1,800	69	.45	
Maple, sugar ⁵ ..	400	3,425	86	.66	3,380	30	.66	
Oak, red ⁵	320	2,258	94	.63	2,370	56	.66	
Oak, white ⁵	320	2,670	94	.63	2,050	45	.68	
Pine, southern :	:	:	:	:	:	:	:	
yellow.....	160	1,719	97	.51	1,950	86	.61	
Spruce, Sitka...:	160	1,306	93	.37	1,300	97	.39	
Sweetgum.....	320	1,769	91	.51	1,790	76	.55	
Walnut, black...:	160	2,393	98	.51	2,150	53	.58	
Yellowpoplar ⁵ ..:	320	2,143	100	.50	1,600	84	.45	

¹Results with 4 different resin glues averaged.

²Results are taken from figure 13 in U. S. Department of Agriculture Bulletin 1500, "The Gluing of Wood," by T. R. Truax.

³Joints glued with resin glues conditioned to about 12 percent moisture content; joints glued with casein glues conditioned to about 7 percent moisture content.

⁴Specific gravity based on the oven-dry weight and the volume at test.

⁵Heartwood and sapwood glued separately.

⁶Value recently obtained in studies of the gluing properties of noble fir, but not reported in U. S. Department of Agriculture Bulletin 1500.

Table 2.--Results of gluing 15 species with four cold-setting, urea-resin glues.

Species	Number of specimens:	Glue A			Glue B			Glue C			Glue D		
		Average	shear	wood : specific gravity	Average	shear	wood : specific gravity	Average	shear	wood : specific gravity	Average	shear	wood : specific gravity
		per	glue	strength: failure	per	glue	strength: failure	per	glue	strength: failure	per	glue	strength: failure
		Lb. per sq. in.	Percent	wood : specific gravity	Lb. per sq. in.	Percent	wood : specific gravity	Lb. per sq. in.	Percent	wood : specific gravity	Lb. per sq. in.	Percent	wood : specific gravity
Ash, white ²	40	2,303	99	0.589	2,162	92	0.600	2,279	98	0.607	2,314	98	0.578
Basswood ²	40	1,451	97	.400	1,397	92	.399	1,411	100	.398	1,504	99	.399
Birch, yellow ⁴	80	2,832	98	.605	2,749	93	.611	2,926	96	.618	2,854	99	.617
Douglas-fir ²	40	1,627	98	.502	1,731	96	.491	1,740	98	.491	1,646	98	.504
Fir, noble ²	40	1,579	98	.420	1,590	96	.424	1,668	98	.433	1,690	99	.421
Hickory, pecan ⁴	80	2,088	89	.715	1,915	78	.698	2,001	79	.716	2,061	87	.698
Mahogany ⁵	40	1,969	100	.475	1,892	98	.477	1,923	98	.469	1,913	99	.472
Maple, sugar ⁴	80	3,445	93	.662	3,196	63	.655	3,575	89	.659	3,487	97	.665
Oak, red ⁴	80	2,378	96	.629	2,073	88	.630	2,209	95	.623	2,374	98	.642
Oak, white ⁴	80	2,775	94	.631	2,619	91	.634	2,548	93	.631	2,750	98	.631
Pine, southern ²	40	1,820	99	.506	1,509	89	.518	1,817	99	.506	1,732	99	.509
Spruce, Sitka ²	40	1,284	93	.373	1,380	93	.374	1,270	92	.361	1,292	96	.368
Sweetgum ⁴	80	1,830	94	.507	1,664	82	.507	1,785	91	.501	1,797	96	.507
Walnut, black ²	40	2,365	98	.513	2,547	98	.507	2,391	99	.503	2,267	97	.508
Yellowpoplar ⁴	80	2,030	99	.506	2,121	96	.500	2,233	100	.511	2,187	100	.502

¹ Specific gravity of the wood used is based on the oven-dry weight and the volume at approximately 12 percent moisture content.² Mostly sapwood.³ Mixed sapwood and heartwood or not identified.⁴ Heartwood and sapwood glued separately.⁵ Mostly heartwood.⁶ Average of 160 specimens.

Table 3.--Comparison of the results obtained with 5- and 15-minute assembly times on 15 species with cold-setting, urea-resin glues

Species	: Average : 5-minute assembly : 15-minute assembly					
	: specific : -----					
	: gravity : Average : Average : Average : Average					
	: of wood : shear : wood : shear : wood					
	: used ¹ : strength: failure : strength: failure					
		Lb.per	Percent	Lb.per	Percent	
		sq.in.		sq.in.		
Ash, white ²	0.59	2,294	97	2,235	98	
Basswood ².....	.40	1,434	97	1,448	97	
Birch, yellow.....	.61	2,856	96	2,825	97	
Douglas-fir ².....	.49	1,692	97	1,680	97	
Fir, noble ².....	.42	1,634	98	1,630	98	
Hickory, pecan	.71	2,059	84	1,994	83	
Mahogany ².....	.47	1,933	98	1,915	99	
Maple, sugar.....	.66	3,411	84	3,440	87	
Oak, red.....	.63	2,314	95	2,204	93	
Oak, white.....	.63	2,646	94	2,692	95	
Pine, southern						
yellow ².....	.51	1,795	97	1,743	96	
Spruce, Sitka ².....	.37	1,306	94	1,312	92	
Sweetgum.....	.51	1,795	91	1,743	90	
Walnut, black ².....	.51	2,369	98	2,416	99	
Yellowpoplar.....	.50	2,151	99	2,135	99	
Average result for :						
species tested.....		2,112	94	2,094	94	

¹Specific gravity based on the oven-dry weight and the volume at approximately 12 percent moisture content.

²Test values are based on 80 specimens; for the other species the test values are based on 160 specimens, except for sugar maple for which the values are based on 200 specimens.

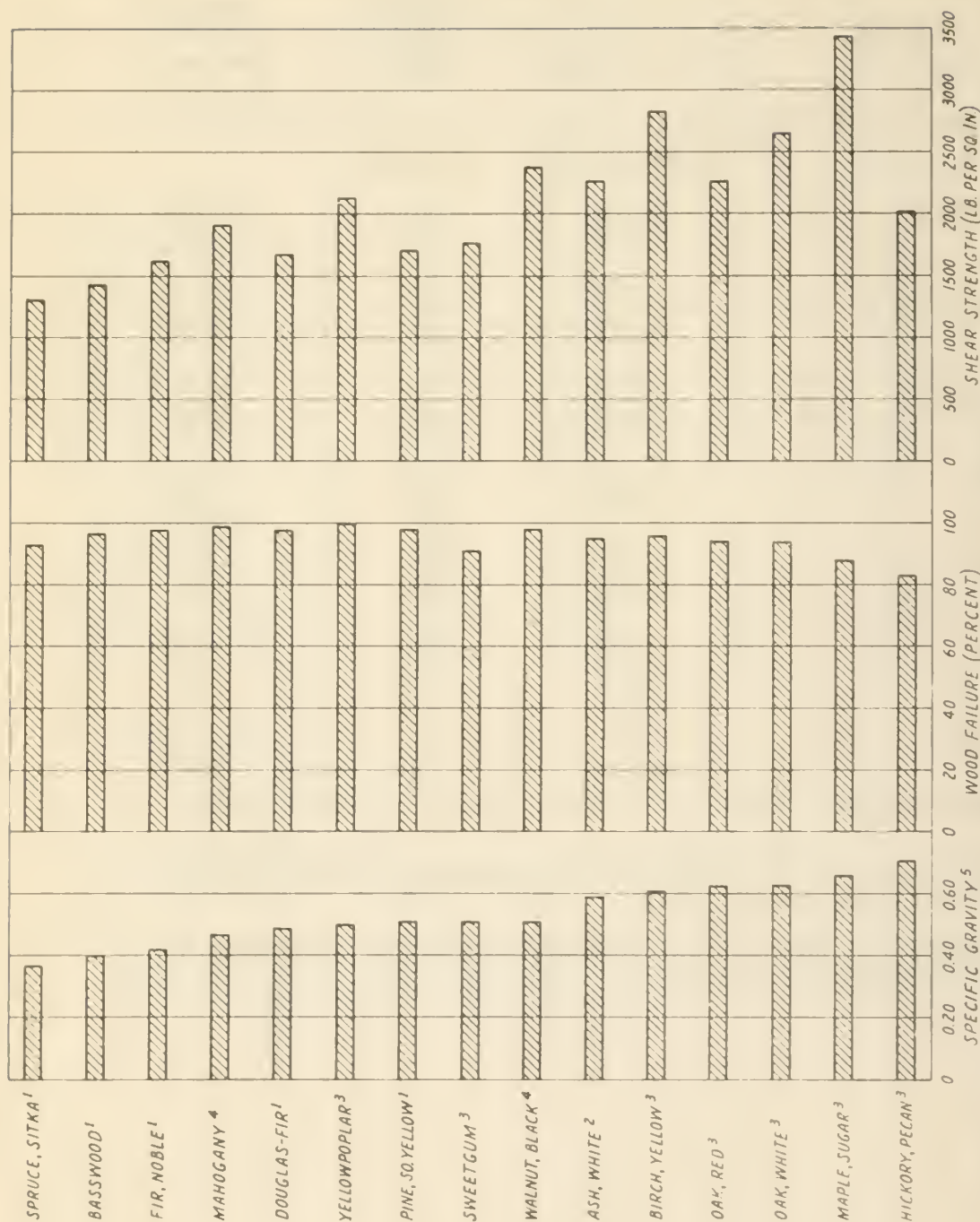
Table 4.--Results of gluing heartwood and sapwood of 7 species
of wood with cold-setting, urea-resin glues

(Heartwood - H; Sapwood - S)

Species		: Average ¹ : shear : strength :	: Average ¹ : wood : failure :	: Average ² : specific : gravity of : wood used
		: <u>Lb. per sq. in.</u> :	: <u>Percent</u> :	
Birch, yellow	H	: 2,783	: 96	: 0.624
	S	: 2,398	: 97	: .602
Hickory, pecan	H	: 1,875	: 80	: .709
	S	: 2,157	: 87	: .704
Maple, sugar	H	: 3,445	: 89	: .664
	S	: 3,404	: 82	: .656
Oak, red	H	: 2,219	: 94	: .614
	S	: 2,298	: 94	: .648
Oak, white	H	: 2,736	: 93	: .672
	S	: 2,602	: 96	: .592
Sweetgum	H	: 1,902	: 85	: .536
	S	: 1,635	: 94	: .473
Yellowpoplar	H	: 2,092	: 99	: .507
	S	: 2,194	: 99	: .503

¹Each test value is the average of 160 specimens or more, glued with 4 different resin glues.

²Specific gravity based on the oven-dry weight and the volume at 12 percent moisture content.



1-MIXED HEARTWOOD AND SAPWOOD OR NOT IDENTIFIED. 2-MOSTLY SAPWOOD. 3-HEARTWOOD AND SAPWOOD GLUED SEPARATELY.
4-MOSTLY HEARTWOOD 5-AVERAGE SPECIFIC GRAVITY OF THE WOOD USED IS BASED ON THE OVEN-DRY WEIGHT AND THE VOLUME
AT APPROXIMATELY 12% MOISTURE CONTENT.

FIG. 1
RESULTS OF TESTS ON JOINTS OF VARIOUS WOODS
GLUED WITH COLD-SETTING UREA-RESIN GLUES (AVERAGES FOR 4 GLUES)